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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : G02B 6/34

A1

(11) International Publication Number: WO 87/ 01818

(43) International Publication Date: 26 March 1987 (26.03.87)

(21) International Application Number: PCT/GB86/00571

(22) International Filing Date: 23 September 1986 (23.09.86)

(31) Priority Application Number: 8523407

(32) Priority Date: 23 September 1985 (23.09.85)

(33) Priority Country: GB

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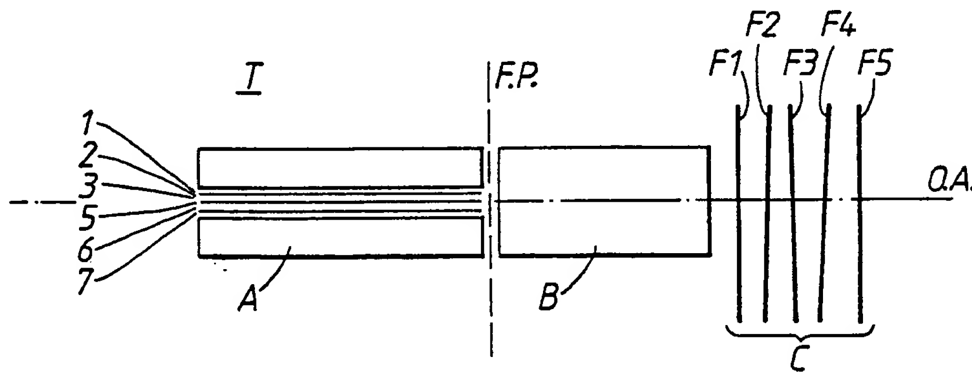
(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), IT (European patent), LU (European patent), NL (European patent), SE (European patent), US.

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

1DS#2

(54) Title: FIBRE OPTIC ASSEMBLY



(57) Abstract

A tapping device (T) for a wavelength multiplexed fibre optic system, the device comprising an array of optical fibres (1-7) a lens member (B) for collimating light from and/or focussing light upon an end face of the optical fibres, and a group of wavelength selective mirror filters (F1-F5), wherein one of the fibres provides a multiplexed link input port (1), another of the fibres provides a multiplexed link output port (7), and at least a further pair of fibres provides, respectively, an input tap (2) and an output tap (3), and wherein the filters (F1-F5) are arranged in wavelength sequential order and are angularly inclined for coupling light of appropriate select wavelength between the input port (1) and the output port (7), the input tap (2) and the output port (7), and the input port (1) and the output tap (3).

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FIBRE OPTIC ASSEMBLY

The present invention concerns improvements in or relating to fibre-optic tapping assemblages for use in wavelength-multiplexed fibre-optic systems. These function to facilitate the selective insertion and/or removal of one or more signal wavelength bands from a fibre-optic link carrying many wavelength multiplexed bands.

Conventional tapping assemblages utilise two discrete tapping components (tap-in and tap-out), usually arranged in series, for each wavelength accessed. In such assemblages, therefore, the component-count is high and connector losses considerable. Furthermore, band-pass and band-stop types of filter are usual in the assemblages. These are most often complicated and costly.

The present invention is intended to provide a remedy to the shortcomings aforesaid.

In accordance with a first aspect of this invention, therefore, there is provided a tapping device for a wavelength multiplexed fibre optic system, the device comprising an array of optical fibres, a lens member for collimating light from and/or focussing light upon an end face of the optical fibres, and a group of wavelength selective mirror filters, wherein one of the fibres

provides a multiplexed link input port, another of the fibres provides a multiplexed link output port, and at least a further pair of the fibres provides, respectively, an input tap and an output tap, and wherein the filters are arranged in wavelength sequential order and are angularly inclined for coupling light of appropriate select wavelength between the input port and the output port, the input tap and the output port, and the input port and the output tap. Preferably, the tapping device comprises for each signal wavelength accessable by the device, an input tap and an output tap, a wavelength selective mirror filter for each accessable wavelength, each such filter being angularly inclined for coupling light between the input port and the corresponding output tap and between the corresponding input tap and the output port, and further filters, angularly inclined for coupling light between the input port and the output port, for reflecting light at wavelength below, above and intermediate to said accessable wavelengths.

In carrying out the present invention, the array may comprise a closely packed bundle of monomode or multimode optical fibres conveniently contained within a tubular housing (e.g. a glass capillary tube) of appropriate bore dimensions for holding the optical fibres in position.

The lens member conveniently may comprise a rod-shaped graded refractive index (GRIN) lens which serves the dual function of collimating light received from the optical fibre array and of focusing light reflected back from the wavelength-selective filter group on to selected end faces of the optical fibre array. This, or a conventional rod lens, is conducive with simple mechanical alignment.

The array of closely packed optical fibres and use also of a closely stacked group of wavelength-selective filters in combination with the preferred use of a rod-like GRIN lens, enables a relatively simple, compact device of relatively low cost and ease of manufacture to be produced, having relatively low losses for the following reasons:-

a) Low off-axis lens aberrations due to the use of a closely packed optical fibre array;
b) Discrete wavelength-selective filters are used;
c) Low lens aberrations due to minimal amount of collimating and focusing carried out for a given number of channels;
d) Minimal number of optical components; and,
e) Short optical path lengths.

The mirror filter group may be comprised of long-wave pass filters and thus of relatively straightforward

construction and low cost.

In accordance with a second aspect of the invention there is provided a fibre optic tapping assemblage, the assemblage comprising a tapping device as aforesaid, and including a signal source connected to said input tap, for inserting a first signal of a predetermined wavelength; and, signal receiving means connected to said output tap, receptive to a second signal of a predetermined wavelength, for removing said second signal.

Advantageously, given appropriate selection and arrangement of the fibres and the filters, said first and second signals may be of a common select wavelength lying within the operational wavelength range of the assemblage and system. Signals of common wavelength may be inserted and removed. Alternatively, however, it is noted that the first and second signals may be of different channel wavelength.

The invention affords wavelength selective access on and off a fibre-optic link capable of carrying many wavelengths and noteably incorporates but a single coupling component, the tapping device above mentioned. When compared with state-of-art assemblages which require two discrete components for each wavelength channel accessed, it can be seen that optical and connector losses are much reduced as many sources for such losses have been eliminated.

In accordance with a further aspect of the invention there is provided a wavelength-multiplexed fibre-optic system comprising in co-operative combination the tapping device or assemblage aforesaid together with at least one multiplexer/demultiplexer component, each incorporating a fibre array and lens member of corresponding identical construction.

In the drawings accompanying this specification:-

Figure 1 is a schematic illustration showing a tapping assemblage configured in accordance with the invention;

Figure 2 is an enlarged and simplified elevational view of a tapping device, part of the assemblage, illustrated in the preceding figure;

Figure 3 is an end view of a fibre array, part of this device, and shows fibre and signal wavelength designation;

Figure 4 is an illustration of a reflection mapping function for one of the device mirror filters; and,

Figure 5 is a schematic representation of a simple wavelength-multiplexed fibre-optic system incorporating as essential part the assemblage shown in the preceding figures.

So that this invention may be better understood, embodiments thereof will now be described, by way of

example only, and with particular reference to the drawings aforesaid.

With reference first to figure 1 there is shown in schematic, a tapping assemblage wherein signals S in a number of wavelength channels $\lambda_1 \ldots \lambda_a \ldots \lambda_b \ldots \lambda_n$ are propogated along a main fibre link to an input port 1 of a tapping device T. One pair of optical fibres, 2 and 3 respectively, provide input and output taps for signals S*, S of one selected wavelength λ_a. A further pair of optical fibres 5 and 6 provide another set of input and output taps for signals S*, S of a longer wavelength λ_b. A signal source - e.g. an input coupler or transmitter (e.g. light-emitting diode) TX, is connected to each input tap, 2 and 6 and, a receiver - e.g. an output coupler or light detector, RX, is connected to each output tap 3 and 5.

The tapping device T of the particular assemblage considered here comprises an array of seven optical fibres, the fibres 1 to 7 just discussed. These are arranged as a circle of six fibres 1 to 6 about a centrally located fibre 7, the whole having an hexagonal close-packed configuration (fig. 3). It is noted, however, that other packing configurations may be employed. It will be especially noted that pairs of fibres are disposed to lie in orthogonal planes - e.g. the

pair consisting of fibres 1 and 3 is orthogonal to the pair consisting of fibres 2 and 7. It is thus possible, using only a single mirror, to couple light between the tap-in fibre 2 and link-out fibre 7 whilst simultaneously providing coupling between the tap-out fibre 3 and the link-in fibre 1, (fig. 4) thus conserving reflection and transmission losses.

The more detailed structure of the tapping device T is shown in Figure 2. The close-packed arrayed of fibres 1 to 7 is contained within the core of a glass capillary tube and ferrule A. The end faces of these fibres 1 to 7 are coplanar and the array is located on or close and near parallel to the optical axis of a graded refractive index lens B. The end faces of the fibres 1 to 7 are located at or close to the focal plane of the lens B so that light emerging from the fibres 1 to 7 will be collimated. Adjacent to the end of the lens B remote from the fibres is an assembly of five wavelength-selective mirror filters F1 to F5. These mirror filters are, for present purposes, of the long-wave pass type and are arranged in a sequential order of increasing wavelength. it is to be noted, however, that other types of filter are not precluded - for example short wave pass type filters may be utilised but arranged in order of decreasing wavelength. Each of the filters F1 to F5 is inclined to

the optical axis in a predetermined manner to provide fibre to fibre reflection mapping as described below. The alignment of the filters F1 to F5 may be accomplished actively by monitoring the fibre outputs whilst setting each filter in angular position by means of thermosetting resin. Alternatively the filters may be held in position by means of suitable shims of calculated thickness.

The filter pass wavelengths and mapping properties are summarised in Table 1:-

Table 1

Filter properties

FILTER	MIN PASS WAVELENGTHS	MAPPED PAIRS
F1	λa	1 & 7; 2 & 6
F2	λ_{a+1}	1 & 3; 2 & 7
F3	λb	1 & 7; 2 & 6
F4	λ_{b+1}	1 & 5; 6 & 7
F5	λ_n	1 & 7; 2 & 6

The operation of this assemblage is as follows:-

(i) The first filter F1 reflects signals in wavelength channels λ_1 to λ_{a-1} from the main fibre link input port fibre 1 back through the lens B to the main fibre link output port fibre 7;

ii) The second filter F2 reflects signal $S(\lambda_a)$ in wavelength channel λ_a from the link-in fibre 1 to a third fibre 3 (the λ_a tap-out). A corrolary of this

mapping is that the second filter F2 will also reflect signals S* (λ_a) of this wavelength λ_a, from the second fibre 2 to the link-out fibre 7. In this way the signal S* (λ_a) can be lauched on the second fibre 2 and will be inserted to be combined with all other signal wavelengths on the common link-out fibre 7.

iii) The filter F3 reflects signals in the wavelength range λ_{a+1} to λ_{b-1} from the first fibre, link-in fibre 1, to the link-out fibre 7.

iv) The fourth filter F4 reflects signal S*(λ_b) to the fifth fibre, tap-out fibre 5. A similar corrolary is that this filter F4 also reflect signal S* (λ_b) of this same frequency from the sixth fibre, a tap-in fibre 6, allowing re-insertion of signal of wavelength λ_b onto the common link-out fibre 7.

v) The remaining filter, filter F5, reflects signals S of longer wavelengths λ_{b+1} to λ_n from link-in fibre 1 to the common link-out fibre 7.

In this way the device T has passed on wavelength bands from a link-in fibre 1 to a link-out fibre 7, removing signals of two wavelengths (λ_a,λ_b) in the process and allowing an option of re-inserting signals at these wavelengths, these signals carrying the original or modified data as required.

A degree of fibre symmetry is generally required so

that the mapping of the reflections described in operations (ii) and (iv) above can occur. An example of this symmetry - in fact four-fold, has been shown already (fig. 4). Using six out-of-seven fibres in a 7-fibre close packed hexagonal regular array allows access to up to two wavelengths. Of these seven fibres, only six have been utilised to carry signal. The remaining fibre however is included to serve as packing and to maintain regular symmetry within the tubular housing. Other packed arrays and mirror filter combinations could be used to allow access to more than two wavelengths.

Examples of simpler assemblages may be readily seen from inspection of the accompanying drawings. For the sake of brevity some of these are listed in table 2 below:-

Table 2

FUNCTION	FIBRES USED	MIRRORS
Tap-in (λ_a)+Tap-out (λ_a)	1,2,3 & 7	F2 + F1 &/or F5
Tap-in (λ_b)+Tap-out (λ_b)	1,5,6 & 7	F4 + F3 &/or F5
Tap-in (λ_a)+Tap-out (λ_b)	1,2,5 & 7	F2 to F4 + F1 &/or F5
Tap-in (λ_b)+Tap-out (λ_a)	1,3,6 & 7	F2 to F4 + F1 &/or F5

From inspection of table 2, it can be seen that a filter is requisite for each wavelength accessed. Link-in and Link-out fibre mapping filters are also included to reflect light as wavelengths below, above and intermediate

to the access wavelengths.

Other configurations of fibres, suitable for the purposes described herein, will be apparent to those of skill in this art, and are not precluded from the scope of this invention.

To illustrate the use of the above described tapping assemblage in a wavelength-multiplexed fibre link system, the assemblage is shown in co-operative arrangement with multiplexer and demultiplexer components M and D (see figure 5). These latter components M and D may be of identical construction.

These components each comprise a fibre array and lens as shown in figures 2 and 3 preceding.

These components M and D each include a collection of wavelength selective mirror filters also arranged in wavelength sequence. These mirrors, however, are six in number, and, in distinction to the collection described herein for the assemblage, are oriented relative to the optical axis of the lens so as to map each of the peripheral fibres 1 to 6 onto the centrally located fibre 7. It is noted that it is an advantage of this sytem that the fibre and lens construction can be arranged to be identical for the multiplexer M, the demultiplexer D and the tapping device T of the assemblage. Furthermore, mirror filters of similar type may be adopted.

CLAIMS

1. A tapping device for a wavelength multiplexed fibre optic system, the device comprising an array of optical fibres, a lens member for collimating light from and/or focussing light upon an end face of the optical fibres, and a group of wavelength selective mirror filters, wherein one of the fibres provides a multiplexed link input port, another of the fibres provides a multiplexed link output port, and at least a further pair of fibres provides, respectively, an input tap and an output tap, and wherein the filters are arranged in wavelength sequential order and are angularly inclined for coupling light of appropriate select wavelength between the input port and the output port, the input tap and the output port, and the input port and the output tap.

2. A tapping device according to claim 1 comprising, for each signal wavelength accessable by the device, an input tap and an output tap, a wavelength selective mirror filter for each accessable wavelength, each such filter being angularly inclined for coupling light between the input port and the corresponding output tap and between the corresponding input tap and the output port, and further filters, angularly inclined for coupling light

between the input port and the output port, for reflecting light at wavelengths below, above, and intermediate to said accessable wavelengths.

3. A tapping device according to claim 1 or claim 2 wherein the or each fibre pair comprising the input port and the output tap, and the or each pair comprising the input tap and the output port are arranged substantially orthogonal to each other, each pair being coupled by a common mirror filter.

4. A tapping device according to any one of claims 1 to 3 wherein the lens members comprises a graded refractive index lens.

5. A tapping device according to any one of the preceding claims wherein the mirror filters comprise long wave pass filters.

6. A fibre optic tapping assemblage comprising a tapping device according to any one of claims 1 to 5, at least one signal source connected to an input tap for inserting a

first signal of a predetermined wavelength, and at least one signal receiving means connected to an output tap receptive to a second signal of predetermined wavelength, for removing said second signal from the assemblage.

7. An assemblage according to claim 6 wherein the first and second signals have a common select wavelength.

8. A wavelength multiplexed fibre optic system comprising a tapping device according to any one of claims 1 to 5 or an assemblage according to claim 6 or claim 7 in combination with at least one multiplexer and/or demultiplexer component, each incorporating a fibre array and lens member of similar construction.

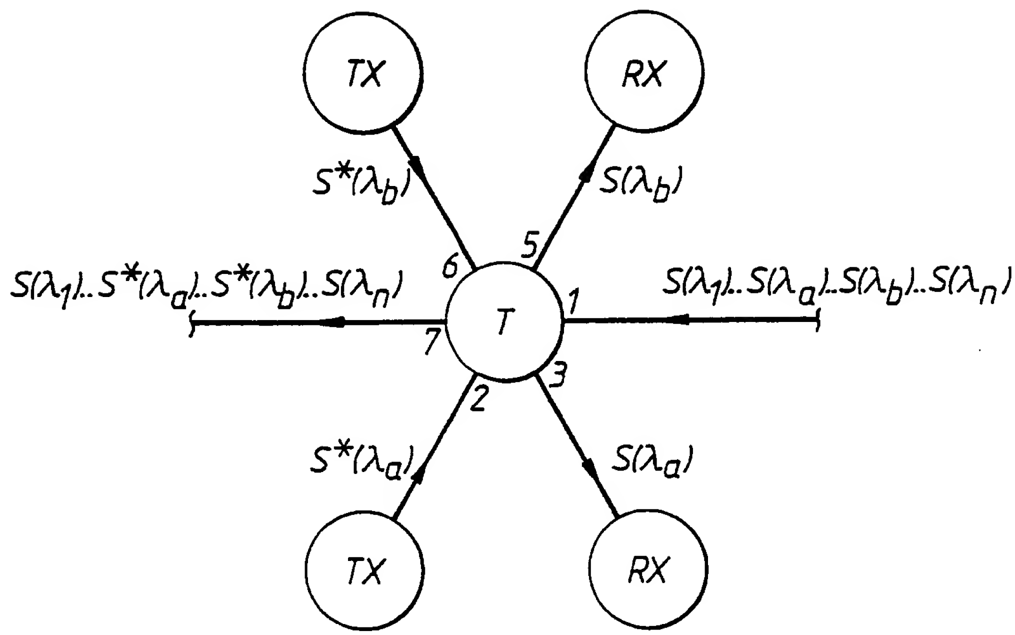
TX
RX
S*(λb)
S(λb)
S(λ1)..S*(λa)..S*(λb)..S(λn)
S(λ1)..S(λa)..S(λb)..S(λn)
T
1
2
3
5
6
7
S*(λa)
S(λa)
TX
RX

FIG. 1.

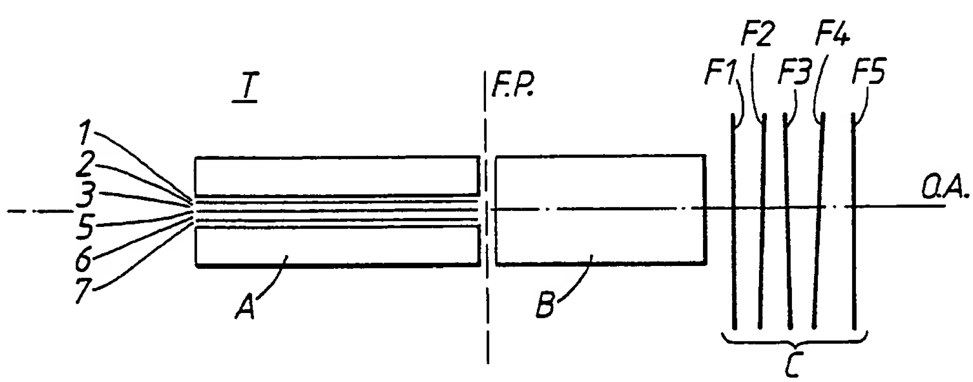
T
F.P.
F1
F2
F3
F4
F5
1
2
3
5
6
7
O.A.
A
B
C

FIG. 2.

2/2

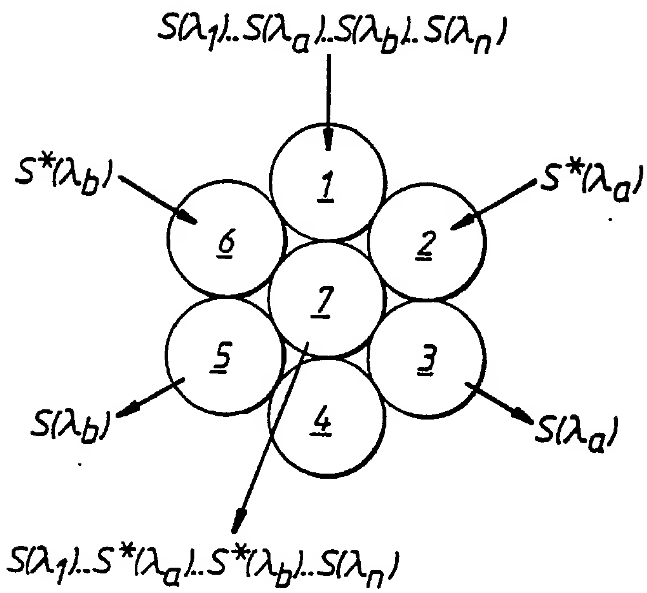

FIG. 3.

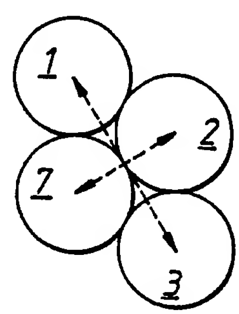

FIG. 4.

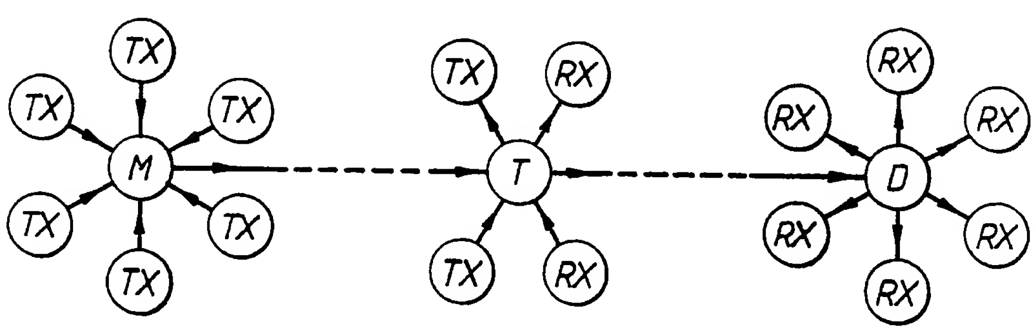

FIG. 5.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 86/00571

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: G 02 B 6/34

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	G 02 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X,P	EP, A, 0157529 (PLESSEY OVERSEAS) 9 October 1985, see claims 1,3,4; page 5, line 20 - page 6, line 11; figures 1,2	1-8
	--	
X	GB, A, 2096350 (WESTERN ELECTRIC) 13 October 1982, see page 2, lines 35-90; figure 2	1-8
	------------	

* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
6th January 1987	06 FEB 1987
International Searching Authority	**Signature of Authorized Officer**
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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON

INTERNATIONAL APPLICATION NO. PCT/GB 86/00571 (SA 14630)

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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A- 0157529	09/10/85	JP-A-	60214317	26/10/85
GB-A- 2096350	13/10/82	FR-A,B	2502347	24/09/82
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		CA-A-	1172080	07/08/84
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